NASA TECHNICAL TRANSLATION NASA TT F-14,058

METHOD OF MEASUREMENT AND ANAYLSIS OF NOISE OF AN AIRCRAFT IN FLIGHT

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Translation of: "Méthodes de Mesure et d'Analyse du Bruit des Avions en Vol", Société Nationale d'Étude et de Construction de Moteurs d'Aviation, Paris and Office National d'Études et de Recherches Aérospatiales, Chatillon, 1971, 27 pages (Paper presented at the Tenth International Aeronautical Congress of AFITA, Paris, June 1-3, 1971).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION WASHINGTON, D. C. 20546 DECEMBER 1971

METHOD OF MEASUREMENT AND ANALYSIS OF NOISE OF AN AIRCRAFT IN FLIGHT

S. Auzolle(1) and J. Hay(2)

ABSTRACT. An aircraft noise measuring installation developed by several French organizations for full-scale measurements of aircraft in flight is described. The system uses an extensive measurement chain network equipped with microphones, cinetheodolites and magnetic tape recorders. Computer analysis allows the study of annoyance level, directivity and statistical properties of the noise.

SUMMARY /1*

For several years, manufacturers of turbojets and research organizations have worked on the problem of aircraft noise. The S.N.E.C.M.A. and the O.N.E.R.A. have performed numerous studies of aeronautical acoustics. Several of these have shown that the measurement and analysis of the noise emitted by aircraft in flight are indispensable for carrying out general studies and also for the preparation of acoustic certifications. This work made it necessary to study and build a variety of special instruments. With them, it was possible to give commands from a central station which can start and stop all the measurement positions, to synchronize recordings (noise, trajectory of the aircraft, motor parameters), and to acquire test data recorded on analog coded tapes. The spectral analysis is carried out in a laboratory. An integrating real time analyzer is used in an automatic network. It presents the result in a form which is compatible with analysis by a computer.

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*Numbers in the margin indicate pagination in the original foreign text.

(1) SNECMA - Paris

(2) ONERA - Chatillon

The acoustic results are evaluated in conjunction with the aerodynamic data and trajectory data provided by the test center in flight. The evaluation of the results makes it possible to calculate the annoyance (PNdB - EPNdB) and to study the directivity of the noise in flight. These programs also make it possible to transpose the region flown over into a standard atmosphere and for a given reference distance.

Systematic tests have made it possible to calculate the necessary test conditions in order to obtain results which can be completely evaluated. This consists of number of flights over the terrain to be carried out, trajectories to be flown and calibration of the measurement networks.

I. INTRODUCTION

The problem of aircraft noise which has persisted for several years does not cease to become crucial with the development of air traffic. Builders of turbojets, such as the Société Nationale d'Etude et de Construction de Moteurs d'Aviation, and the research organizations, such as the l'Office National d'Etudes et de Recherches Aérospatiales have at their disposal considerable technical and human resources which are being applied to the problems of aeronautical noise, because of the support of the Transport Ministry and the Army.

Among the above, the measurement and evaluation of acoustic tests carried out on aircraft represents a complement and a logical conclusion of a whole series of preliminary studies. Chronologically, these studies consist of the following:

a) Theoretical studies of the generation mechanisms and the noise prediction of a turbojet.

b) Model studies (in an acoustic chamber, for example) of the noise from different sources and various attenuating devices, such as silencers.

c) Turbojet studies at scale one and on the ground.

In fact, an aircraft will be evaluated and acoustically certified based on these characteristics of noise in flight. These certifications are based on test conditions and are a requirement for newer aircraft.

The measurement of noise of aircraft in flight is indispensable for several reasons:

a) The mathematical modeling of the various noise sources of a turbojet is extremely difficult to realize in flight in practice.

b) The installation of a jet engine on an aircraft produces interaction problems between the acoustic field of this jet engine and the aerodynamic field of the aircraft.

c) By mounting several jet engines on an aircraft, the calculation of the acoustic field and the directivity in flight become more complicated.

d) The flight velocity modifies the basic noise (emitted by the jet, for example), but can also influence the effectiveness of noise attenuation devices studied during static tests.

e) Noise propagation problems: reflections on the ground, atmospheric attenuation, temperature gradients, turbulence due to the wind complicate the prediction of the noise of an aircraft in flight. /2

f) The preparation of the acoustic certification, which is necessary for each new aircraft, makes this kind of test indispensable.

2. CHOICE OF MEASUREMENT AND ANALYSIS TECHNIQUES

2.1. The study of a specific measurement and analysis system of noise of aircraft in flight must of necessity be subjected to a certain number of constraints:

- Accuracy of the entire system: the final result must have a small confidence interval considering the accuracy of each element which makes up the chain.

- Official standards must be met, so that results are obtained which are compatible with acoustic certification conditions.

In addition, certain requirements exist:

1) Requirements for Recording Techniques:

- compatibility with existing measurement equipment for other types of acoustic tests: for example, single track Nagra tape recorders should be used

- ease of utilization and autonomy of the equipment

- compatibility with later automatic analysis (parallel recording of coded command signals).

2) Requirements for Analysis Techniques

- processing of a considerable amount of information. A recording of an overflight with a duration of one minute requires acquiring 3600 spectral components.

- acquistion of the results in a form which is directly compatible with numerical evaluation by computer.

2.2. Since the beginning of 1969, agreement has been reached among all the French organizations concerned with the measurement of aircraft noise. This agreement has been published in a detailed document which imposes accurate measuring conditions. The considerable advantage of this text is the fact that it allows complete coherence among all tests, the exchange of results and data among interested persons, and especially the possibility of common test campaigns among several societies which use the same equipment. This is almost indispensable because of the very high cost of this type of test.

2.3. In practice, it is necessary to have a group of measurements which are completely synchronized:

1) measurement of the acoustic signal

2) measurement of the aircraft trajectory

3) measurement of the motor parameters (rotation rates, pressures, temperature of ejected gases) and aircraft parameters (level or at incidence).

We will make a detailed study of these various measurements and will always stress acoustic measurements in particular.

3. MEASUREMENT AND RECORDING OF THE ACOUSTIC SIGNAL

3.1. Orientation Regarding Adapted Solutions

The parsitic noise due to aircraft traffic on airports "covered" by installations of the FLIGHT TEST CENTER can only be measured over several hours per day. Because of this fact, and also because of rapid fluctuations in meteorological conditions, a measurement program will result in numerous assemblies and disassemblies of the equipment. Therefore, the equipment must be portable. The geographic dispersion of the measurement points extends over several kilometers. Therefore it is indispensable to use single track and autonomous stations.

This is why the O.N.E.R.A. conceived autonomous adapters (type O.N.E.R.A. 20 W 295) connected to half-inch Bruël and Kjaër microphones (Figure 1).

Synchronisation signals must be recorded on the analog tape because of the requirement of dating the analysis for all the measured points within the trajectory time base for any overflight. The separation of the microphones make a radial link between the central clock and the recording stations necessary This link is also used for remote control for starting and stopping the tape recorders. /4

The fact that there is a considerable number of single track recorders means that the microphone signal and the synchronization signals must be recorded on the same track.

Finally, the automatic command analysis logic requires signals which will indicate the beginning and the end of each recording (overflights or calibrations).

3.2. Principle of Operation of the Apparatus

The acoustic command post (ACP)[3] produces commands which are received by the receiving stations[4] (satellite stations). These orders are interpreted and carried out by the latter. Figure 2 shows a diagram of the installation.

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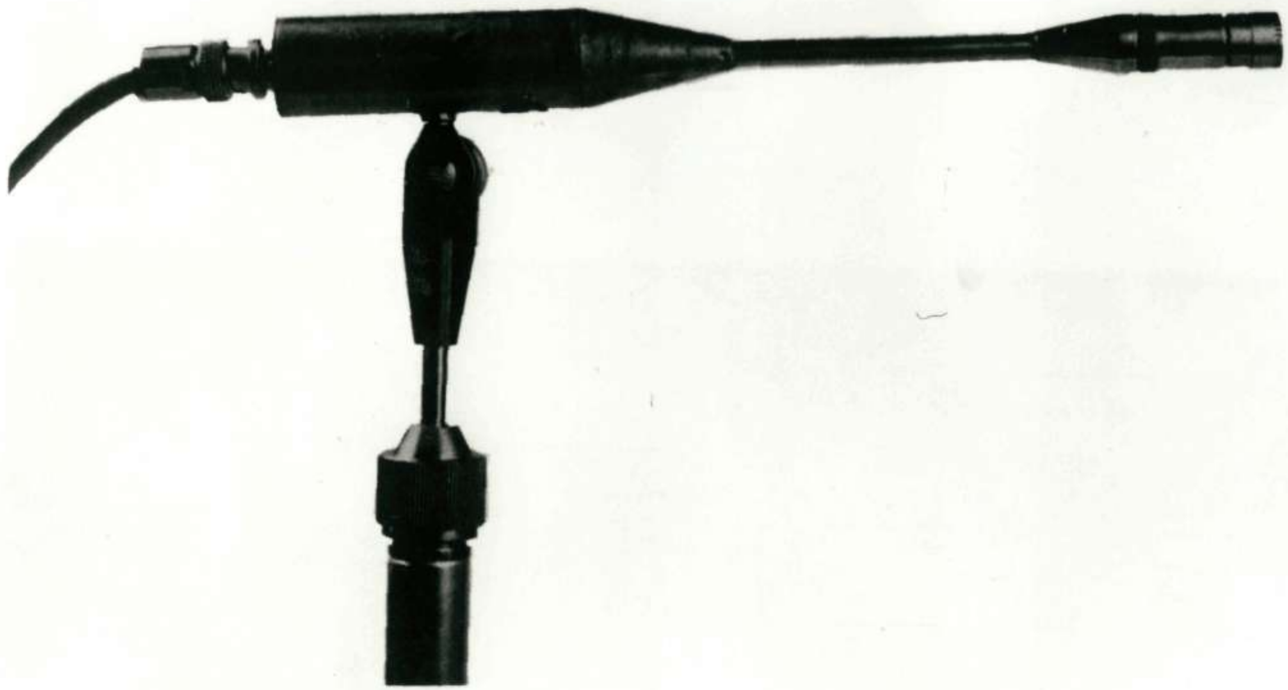
(3) & (4) Types 20 XC 50 and 20 XC 51 of the ONERA nomenclature.



RECORDING UNIT FOR OVER-FLIGHT NOISE

Figure 1

These commands consist of frequency modulation of a HF carrier by a wave train[5]. These wave trains have a duration of 50 ms and are the sum of two sinusoids at the frequencies ($F_1 + F_2$) or ($F_2 + F_3$) or ($F_3 + F_1$), depending on the command to be transmitted.

When a satellite station receives a command, it interprets it by recognizing F_i and F_j. Then it executes it. The blips recorded on the analog magnetic tape are generated at the level of each satellite station. Only the recording times are required and are synchronized by the commands transmitted by HF. Thus, uniform characteristics are obtained for the signals, which would be difficult to obtain by direct recording onto the HF modulation band. Just like the commands, the blips consist of a 15 ms step, the sum of two sinusoids having the frequencies ($f_1 + f_2$) or ($f_1 + f_3$) or ($f_2 + f_3$).

3.3 Recording the Noise from an Overflight

The magnetic recorders at the measurement stations are turned off. The operators associated with one or several satellite stations, which are connected by voice link with the ACP, display the recording gains predicted by calculation for the pass. The acoustic command post then gives the command "go".

This command, which is interpreted by the satellite stations, starts operation of the magnetic recorders and then, after they have run up to speed, /5
a test beginning blip (R_1) is recorded. As soon as the magnetic recorder is running, the station can no longer receive recurring starting commands sent out by the ACP.

After this, the ACP automatically transmits synchronization commands. At each command, the satellite stations prepare and record on analog tapes a synchronization blip (R_3). These commands are marked in time on the time

[5] Transmitter-receiver CSF type MF913.

base of the cinetheodolites at the same time.

The speed of each magnetic recorder is sufficiently constant during any overflight. The synchronization signals are limited to two sequences at the beginning and at the end of the recording. In addition, by simple commutation, it is possible to obtain other time distributions of the commands R_3 using the apparatus. Each of the normalized sequences consists of five R_3 blips. The aperiodic distribution in time makes it possible to control the validity of the blip, even if certain synchronization commands were not properly transmitted.

Thus, after a sufficient delay, the ACP automatically transmits the sequence which defines the time origin for the analysis ("synchronization-beginning sequence").

After the aircraft has passed, the ACP transmits a second sequence ("synchronization-finish sequence"), which makes it possible to verify and even correct the isochronism between experiment and analysis.

Finally, as soon as the command "stop" has been interpreted by the satellite stations, a final test end blip (R_2) is recorded on the tape and the magnetic recorder is stopped. The station then cannot receive recurrent "stop" commands transmitted by the ACP, so that a bad transmission of the preceding commands can be prevented.

Figure 3 shows the structure of the analog recording installation.

Figures 4 and 5 respectively show the command post and one of the satellite stations.

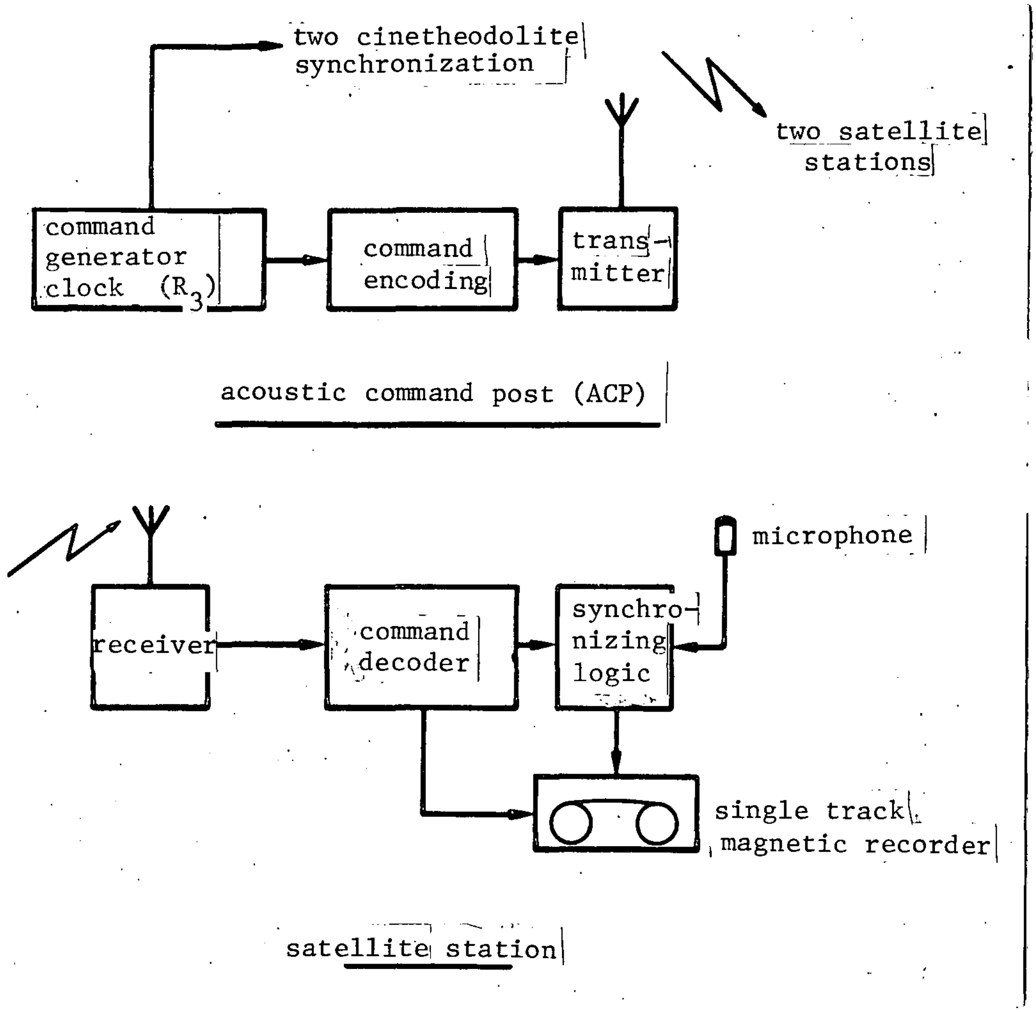
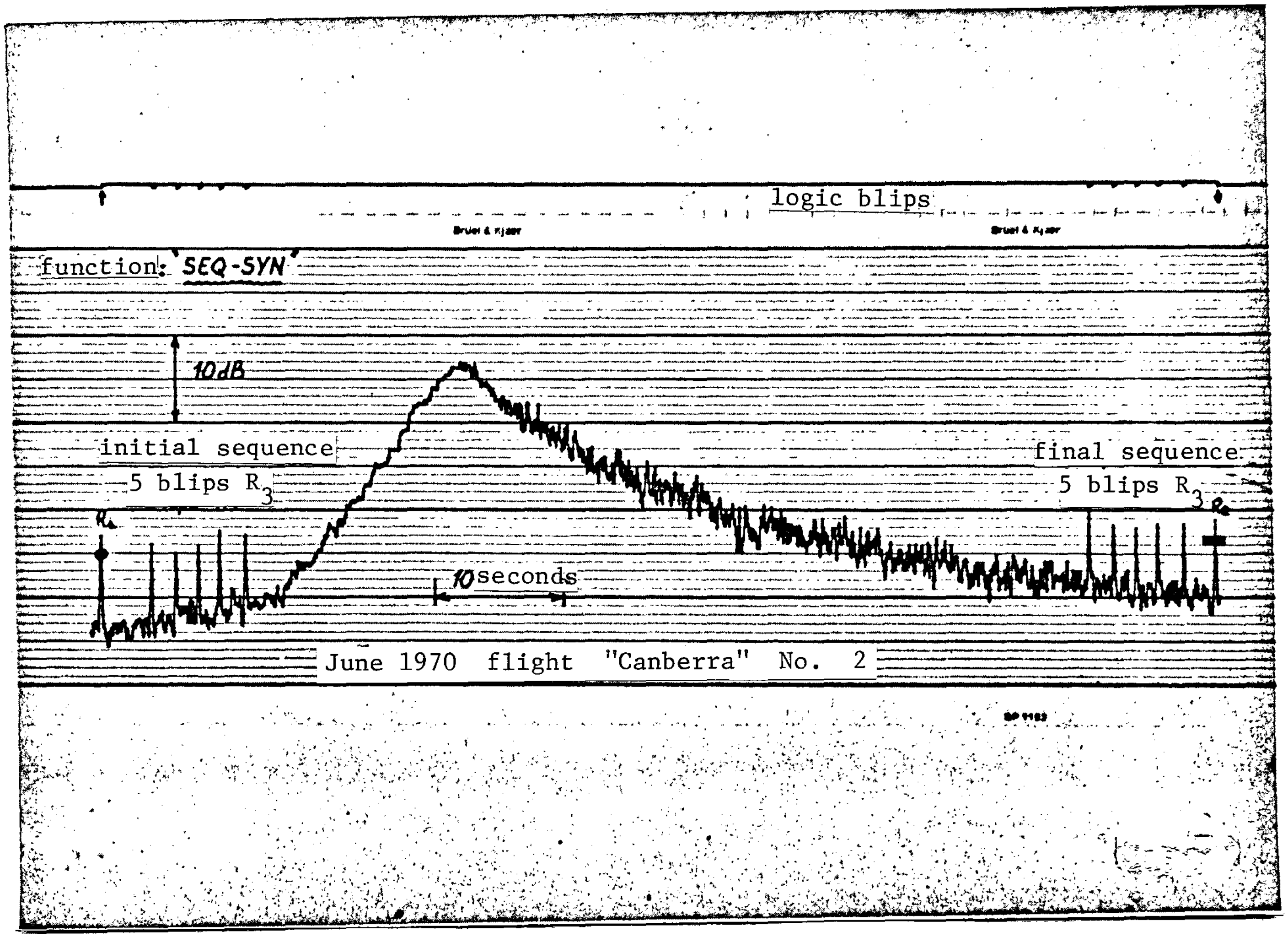

two cinetheodolite
synchronization
two satellite
stations
command
generator
clock (R3)
command
encoding
trans-
mitter
acoustic command post (ACP)
receiver
command
decoder
synchro-
nizing
logic
microphone
single track
magnetic recorder
satellite station

Figure 2



logic blips
function: SEQ-SYN
10dB
initial sequence
5 blips R3
10 seconds
final sequence
5 blips R3
June 1970 flight "Canberra" No. 2

Figure 3

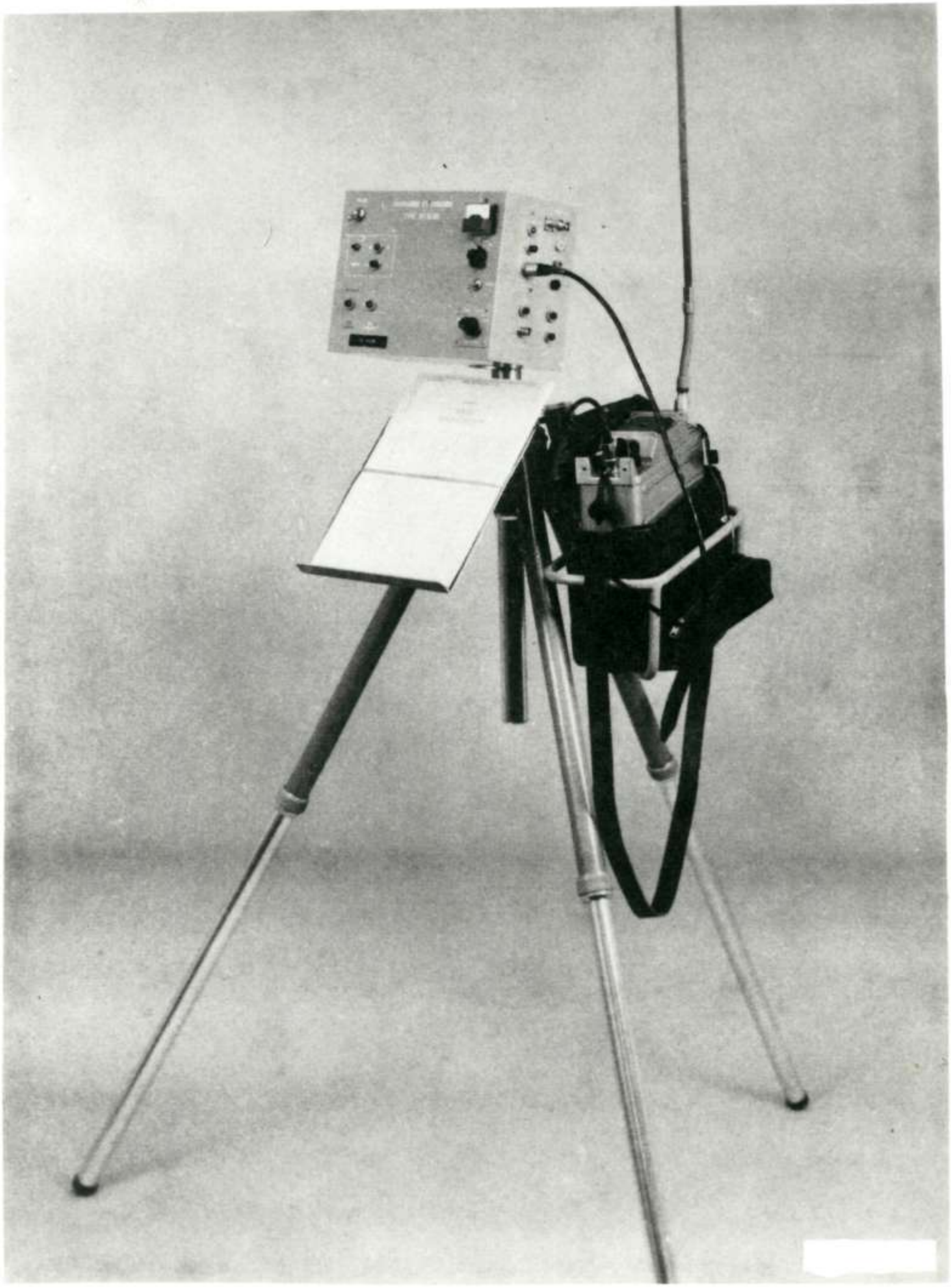


Figure 4

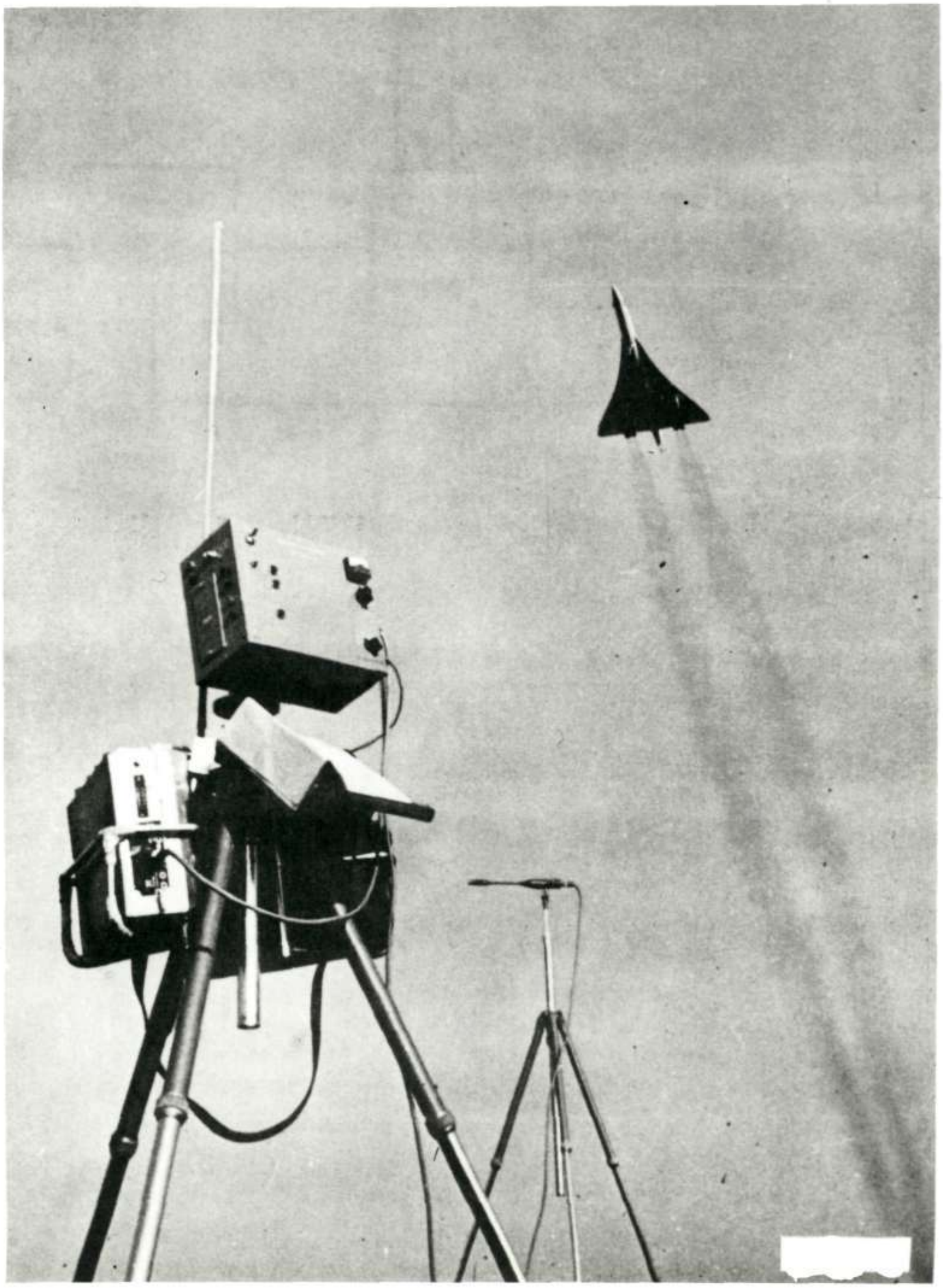


Figure 5

4. AUTOMATIC ANALYSIS OF THE RECORDINGS /6

4.1. Principle (see Figure 6)

The analog magnetic tapes are read at the input of a system which essentially consists of the following:

- a 1/3 octave analyzer in real time (Hewlett-Packard 8054 or General Radio 1921)

- an acquisition unit, which records the spectral information as well as the values from the various counters (in particular, the analysis time)

- a control unit which provides commands for the analog reader, the analyzer, and the numerical recorder. It also is used as the interface between the analyzer and the acquisition unit. This is a logic unit with cables.

- a blip decoder which extracts the blips R_i from the acoustic signal and distributes them in the form of logic levels to the control unit.

The blip R_1 (test begin) puts the system into a waiting mode for the synchronization blips R_3. Each blip R_3 of the "beginning sequence" initiates a time-marked acquisition (this is the same for the "final sequence"). Then, over a duration selected by the operator in order to avoid acquisition which would be too long, the 1/3 octave spectra are recorded on the numerical magnetic tape. Finally, the blip R_2 (end of test) stops the magnetic reader and deactivates the acquisition complex.

When 10 to 20 overflights are recorded on the numerical tape, the tape is processed at the computation center of the O.N.E.R.A. on an IBM 360-50. A highly optimized calculation program reads this tape (this is a raw acquisition tape), corrects certain writing errors, applies the chain corrections, takes the calibrations into account, time marks the spectra and

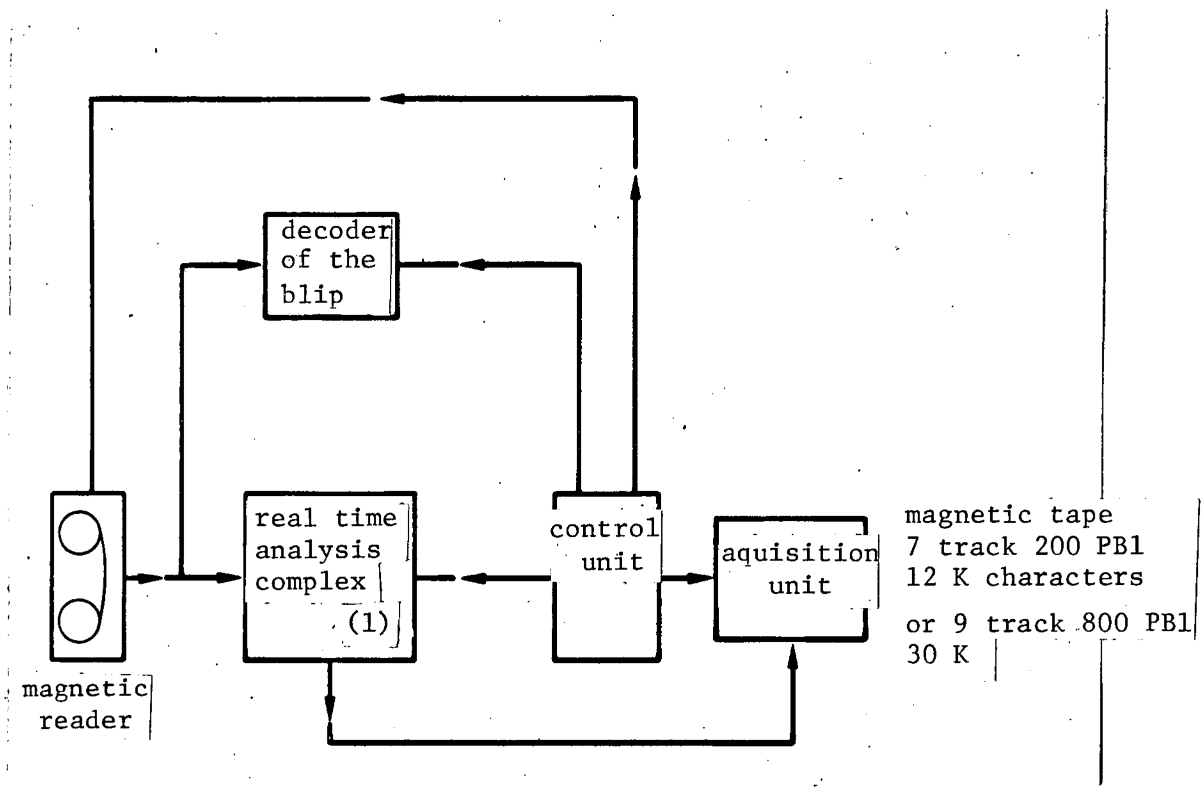


Figure 6. Analysis principle of noise from overflights.

presents the essential results in the form of printed states. It primarily records all of the 1/3 octave spectra[6] expressed in acoustic decibels on a magnetic tape. This tape can be directly used and evaluated by the SNECMA computation center.

Figures 7 and 8 show the two analysis units which made it possible to process almost 1000 overflights ($5 \cdot 10^6$ spectral components) in 1970 during the MYSTERE 20 and CANBERRA programs.

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(6) One spectra every 500 ms.

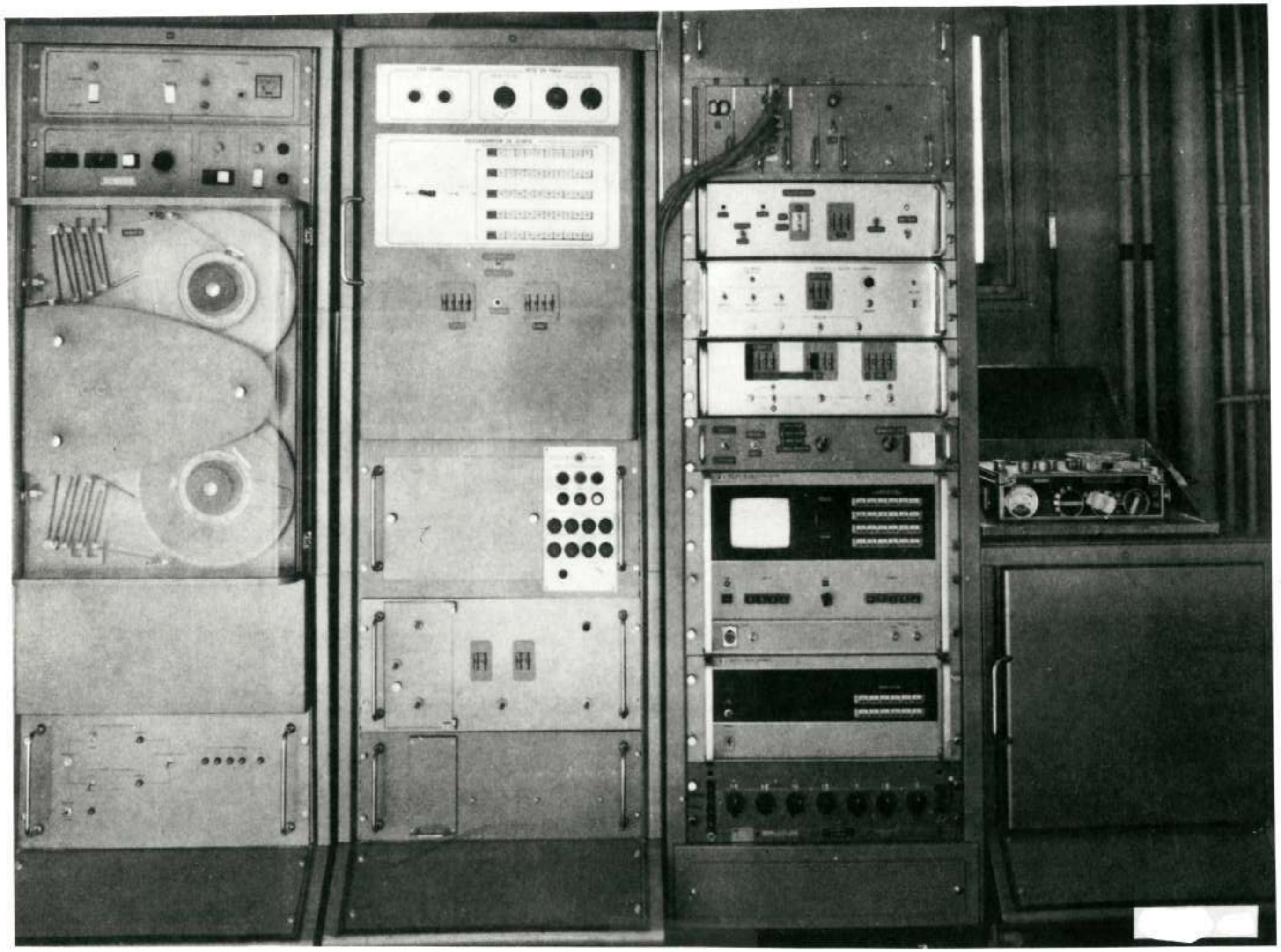

Figure 7

Figure 8

4.2. Development of the Methods /7

This analysis technique, which is inconvenient because it is partially automated, requires a large scientific computer (such as the IBM 360-50) to read a raw acquisition tape. Because of this fact, it comsumes a large amount of time in the central unit. This is not a passive reading process as is the case for a tape assumed to have no errors, which is processed by another computer which is controlled in proportion to the amount being written. This is a reading process where the central unit must verify the information it is storing in the memory.

In order to avoid using a scientific computer essentially for an input-output management function, in order to have automatic analysis of an entire analog tape, and finally in order to allow complex analyzers to be connected and controlled (such as the UPS 6 of Federal Scientific), the O.N.E.R.A. installed an analysis laboratory for acoustic signals this year. This was done within the framework of a study performed for the Service Technique de l'Aéronautique (Technical Aeronautics Service).

This laboratory consists of a C II 10.020 computer connected to real time analyzers. It will be put into service by progressive stages in the course of the second half of 1971. It is designed to support various workers in the studies of aeronautical noise. This will involve classical analyses connected with certain studies of the acoustic signal.

Figure 9 shows the organization of the laboratory.

Figure 10 shows the single track and multi-track analog readers and the real time analyzers which are connected to the inputs of the former.

Figure 11 shows the central unit and the two associated tape machines (9 track - 800 bpi - 60 koctets).*

*Translator's Note: 60k octal words.

Spectral Analysis — Acquisition Equipment

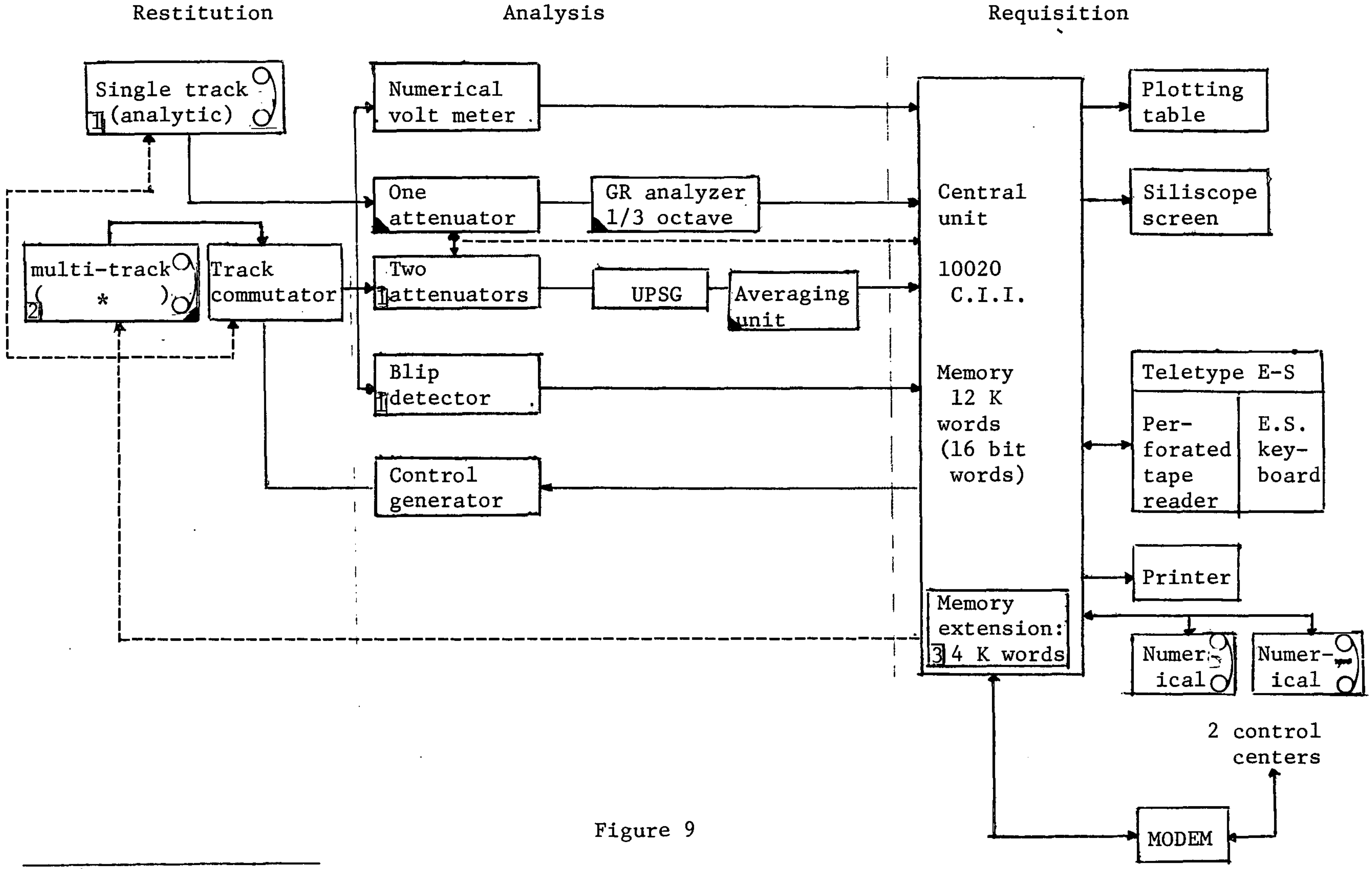

Figure 9

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*Translator's NOTE: Illegible.

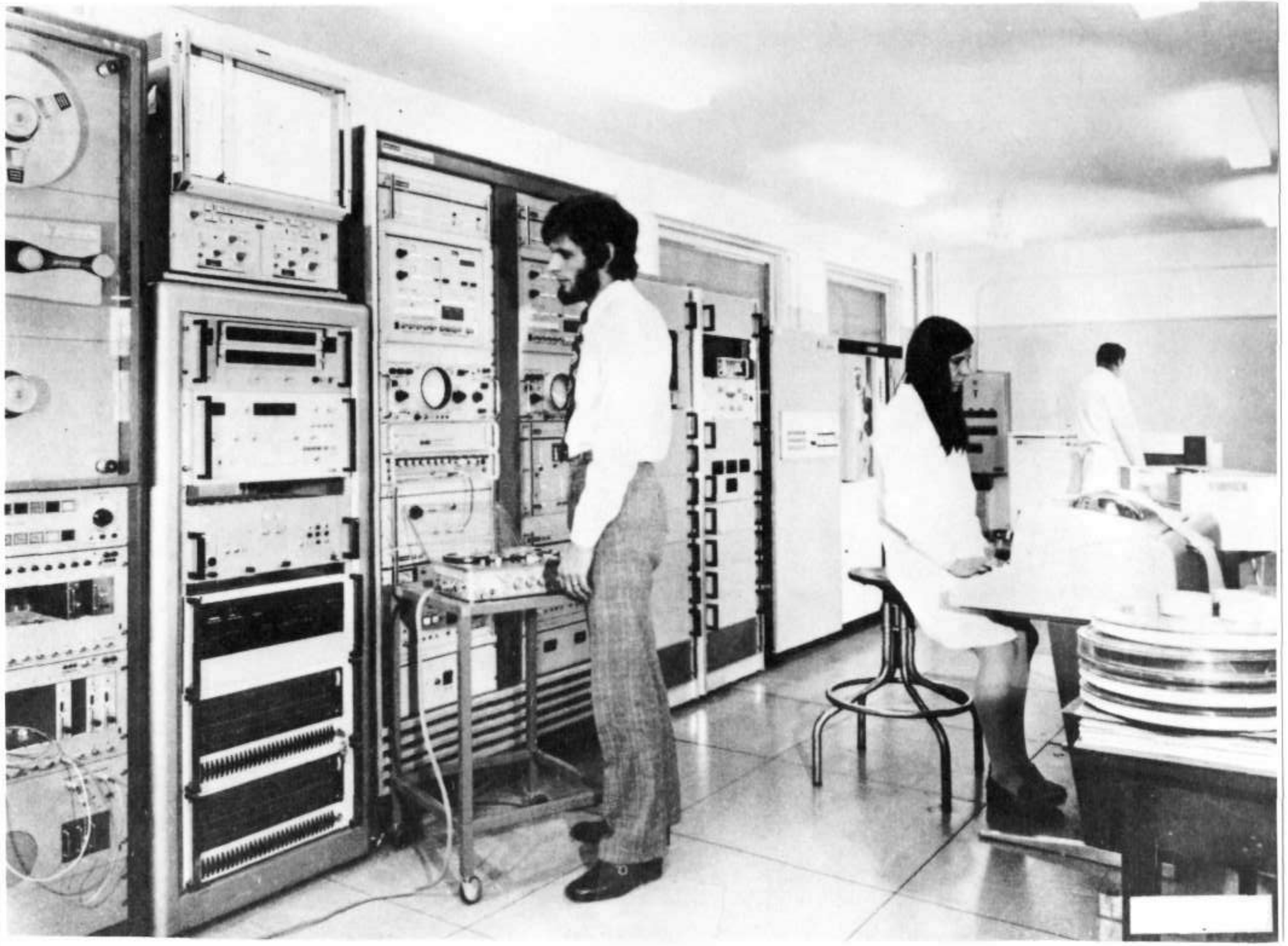


Figure 10

Figure 11

5. ADDITIONAL RECORDINGS

5.1. Trajectory Analysis

This type of measurement is performed by the flight test center using three cinetheodolites which are operated synchronously. The film recordings are analyzed and translated into punched cards which are then processed by a IBM 1800 computer. The trajectory of the aircraft is reconstructed in the form of X - Y - Z coordinates as a function of time. Results given to it during the first tests on punched cards are then put on a numerical magnetic tape, having nine tracks and 800 bpi. It is compatible with the /8
IBM 360 computer of the S.N.E.C.M.A. Figure 12 shows a cinetheodolite station. By the judicious arrangement of the three cameras on the ground, it is possible to obtain the trajectory of interest from the acoustic viewpoint within an accuracy of 2 meters for each of the coordinates in the worst case.

5.2. Motor and the Aircraft Parameters

The aerodynamic parameters of the aircraft and the aerothermodynamic parameters of the engine are recorded either on a pen recorder or a magnetic recorder on board the aircraft.

The trajectory data and the onboard aircraft recordings are synchronized by means of a system which operates on a VHF frequency established by the flight test center. Thus, all results have a common time base.

5.3. Synchronization with Acoustic Recordings

The recordings described above are carried out completely independently of the measurement of the acoustic signal. In order to relate them during the evaluation, a special recorder on the ground is planned. This recorder is connected by means of cables. One track carries the acoustic synchronization signals and the other track, the time base of the flight test center.

Figure 12

Figure 13 shows the diagram of the overall synchronization. The paper strip recorder of the Hussenot type operates at 30 mm/s. Therefore it is possible to obtain a synchronization accuracy greater than 5/110 seconds. A typical ground speed of the aircraft is on the order of 80 m/s. Therefore, the error can amount to 4 meters. This agrees with the accuracy with which the trajectory can be measured.

In order to verify the system, we introduced a known synchronization error at the level of the evaluation program. These calculations were made for an approach case with a very small test altitude (on the order of 120 meters) and an aircraft velocity of 150 kts. If this overflight is reduced to standard conditions, it can be seen that a synchronization error of $\pm$ 1 seconds introduces a variation of $\pm$ 20° in the angle corresponding to the maximum noise spectrum and of $\pm$ 1.6 EPNdB in the characteristic value for the overflight. When the error only amounts to $\pm$ 0.1 seconds, the angle variation is only $\pm$ 2.5° and $\pm$ 0.2 EPNdB. This result shows that the accuracy of the synchronization method utilized is an absolute requirement.

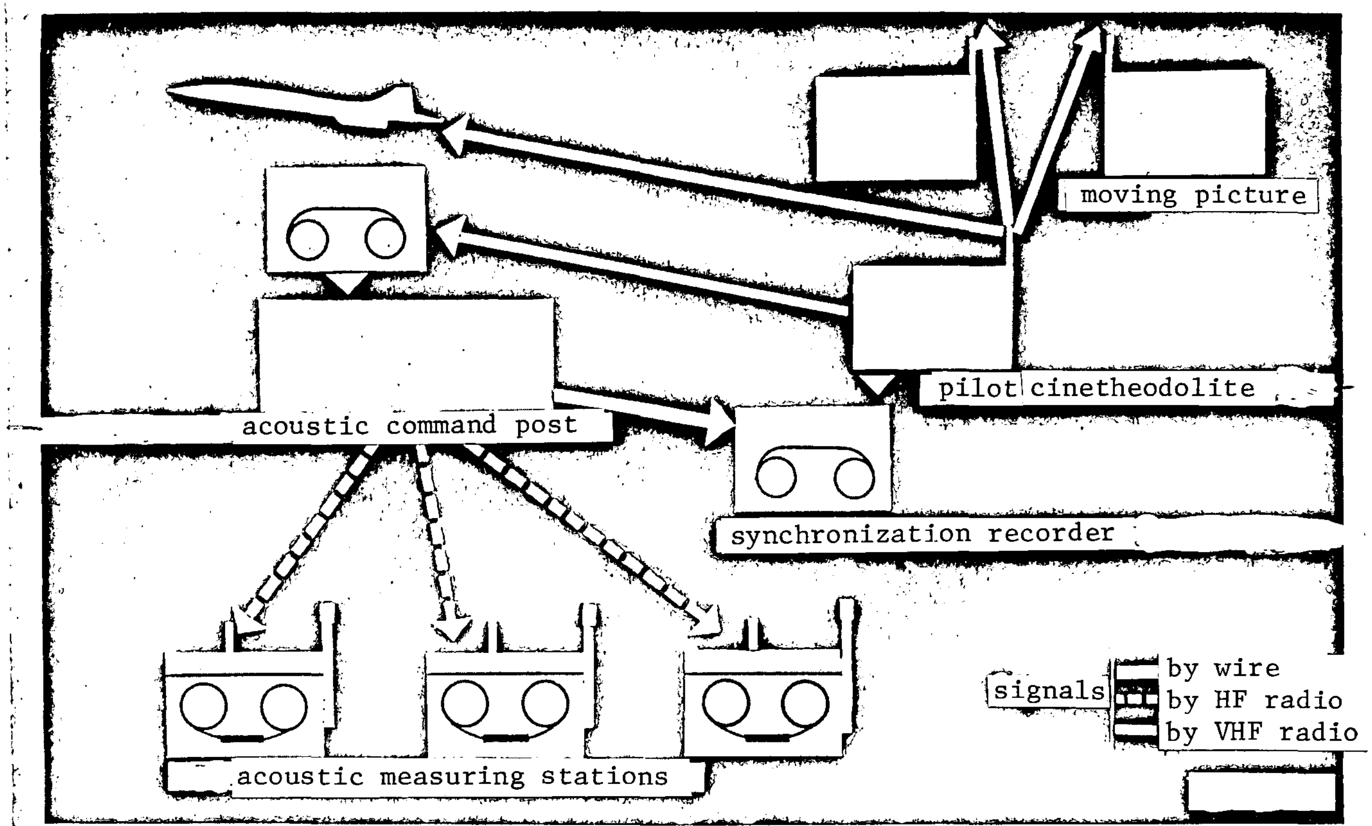
6. TEST PROCEDURES /9

In order to perform and evaluate the tests as accurately as possible, it is necessary to observe strict discipline in the selection of the test program, the equipment for the tests, and the execution of the tests.

6.1. Controls and Calibrations

All the measurement chains are completely checked and calibrated just before the program. This operation can be done by itself and is extremely important, because the tests are carried out at the same time by various organizations which do not always use strictly the same equipment.

The magnetic recorders of each association are set by the magnetic tape used for the test (Scotch 871 tape, recording speed 19 cm/s). The sensitivity



SYNCHRONIZATION and REMOTE COMMANDS

Figure 13

of each recorder is adjusted with the corresponding remote control chain, so that the recording sensitivity of the control signals will be exactly matched. This setting is not changed during the course of the tests. The determination of the response curves of the various chains must be known beforehand, so that the azimuth setting of the recording heads and of the reading heads is checked. Also, this establishes that there are no noticeable defects in the heads and that all the magnetic recorders from the various associations will be compatible.

One control carried out on the analysis level of the deviations in the running speed of the magnetic recorders showed that there was a maximum deviation of 0.2% compared with the "real time" of recording on the ground. It should be noted that, if this deviation becomes substantial, a correction can be made when the signal is analyzed.

Once the magnetic recorders have been set, each chain is calibrated completely in two different ways. This is shown in a diagram of Figure 14. First a pressure calibration is carried out from the microphone of the complete chain using the "driving grille"* method. The chain is excited by means of a sinusoidal signal. Then a white noise electrical calibration of the entire chain is carried out, with the exception of the microphone. Among other things, this operation is intended to control the response curves of the microphones supplied by the manufacturer.

The magnetic calibration recorder tapes are read again by the analysis magnetic recorders. The measured response curves are introduced into the computer, after grille* and incidence corrections of the microphone have been made.

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*Translator's Note: Literal translation. Not enough information is available to give a more accurate translation here.

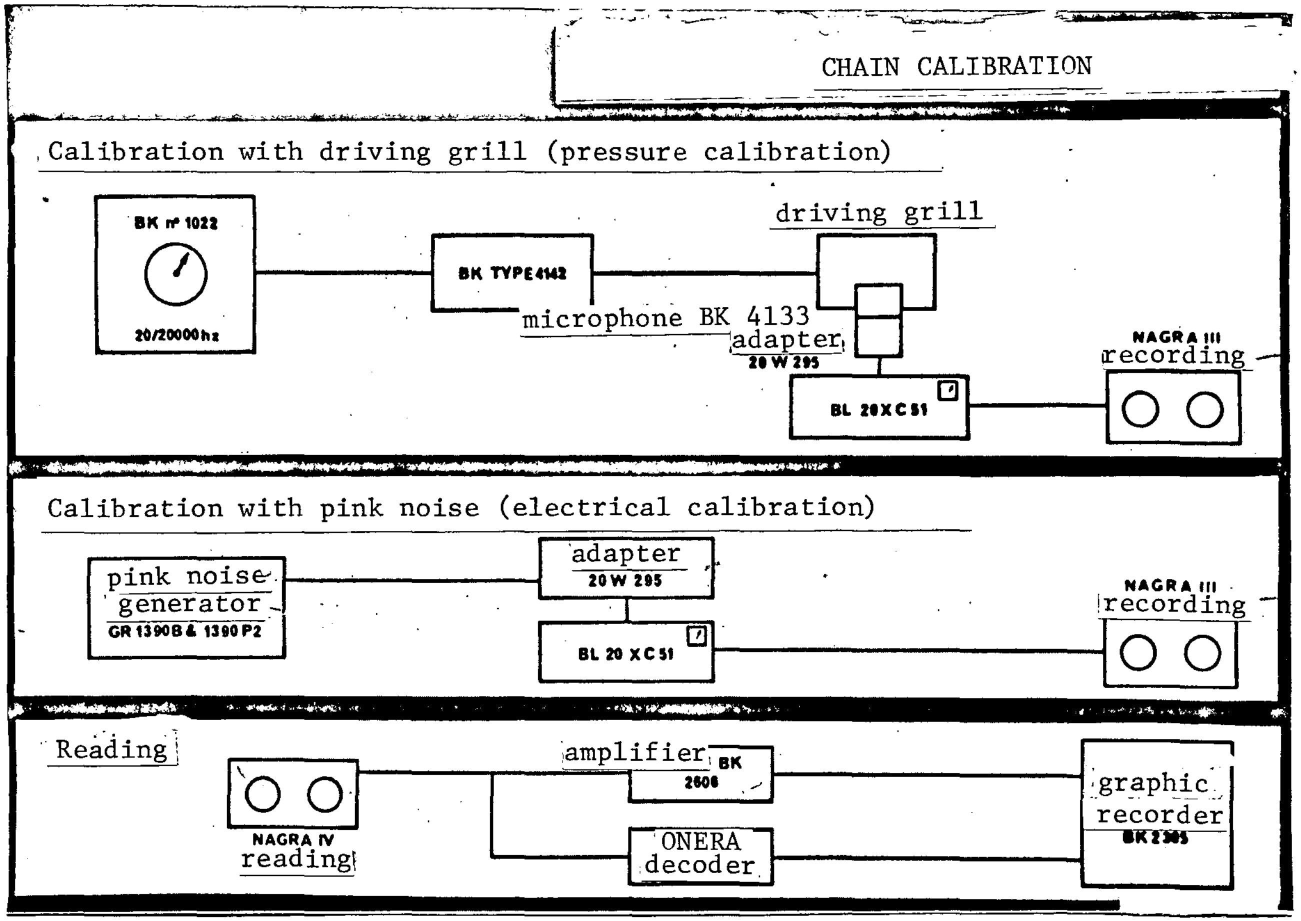

CHAIN CALIBRATION
Calibration with driving grill (pressure calibration)
BK nº 1022
20/20000 hz
BK TYPE 4142
driving grill
microphone BK 4133
adapter
20 W 295
NAGRA III
recording
BL 20 X C 51
Calibration with pink noise (electrical calibration)
pink noise generator
GR 1390B & 1390 P2
adapter
20 W 295
BL 20 X C 51
NAGRA III
recording
Reading
NAGRA IV
reading
amplifier
BK 2606
ONERA decoder
graphic recorder
BK 2305

Figure 14

With these precautions, the accuracy of the measurement and analysis system is estimated to be better than 1 dB. It should be noted that the reference level recorded during the test with a membrane microphone can vary within the range ± 0.2 db. /10

In this connection, the membrane microphones were modified in order to obtain a 500 Hz signal (instead of 250 Hz). This is done so that the reference was recorded at a frequency at which the response curves of the magnetic recorders are essentially linear.

6.3. Selection of the Microphone Positions (see Figure 15)

The membrane of the microphone is placed at a height of 1.2 meters above the ground. Its orientation is such that the aircraft noise will arrive at grazing incidence, no matter what the position of the aircraft on its trajectory. This selection modifies the response of the microphone only slightly at the higher frequencies. This makes it possible to introduce only one response curve per measurement chain for a complete overflight.

The arrangement of the microphones on the ground causes no problems when the noise tests are carried out at Istres. This is due to the fact that the ground is remarkably flat (altitude of the ground 21 ± 2 meters) and is very homogeneous. In addition, the fact that there is almost no vegetation or obstacles makes it possible to carry out acoustic measurements under excellent conditions.

According to the test programs, the microphones are placed either at certification control points or to the side of flight paths in a cross-shaped arrangement. This completely defines the acoustic field of the aircraft which is necessary for directivity studies of the noise in flight.

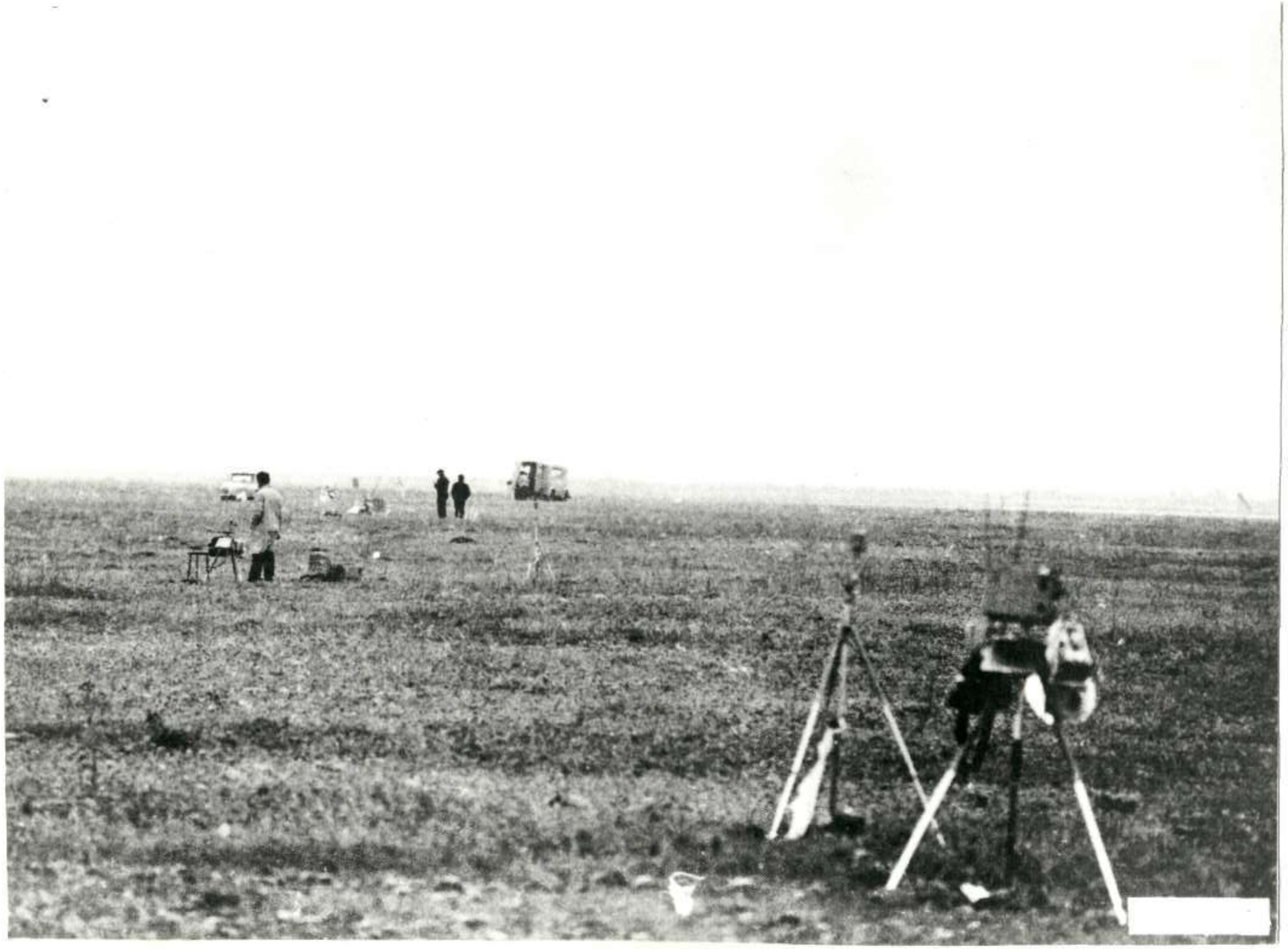


Figure 15

Since the measurement points are very far away from each other, a radio voice link at HF frequencies to each operator must be provided. In addition, there is a VMF (or UMF) link between the control tower, the aircraft and the cinetheodolite stations. Figure 16 shows a diagram of these voice links. Since they operate on two distinct HF and VMF frequencies, there will be no interference between communications on these links and the air traffic directions. These messages are of a completely different nature than the acoustic measurements. The connection between the two is only made at the central command post.

6.3. Test conditions /11

For each test, an additional series of measurements must be made.

6.3.1. Atmospheric Conditions

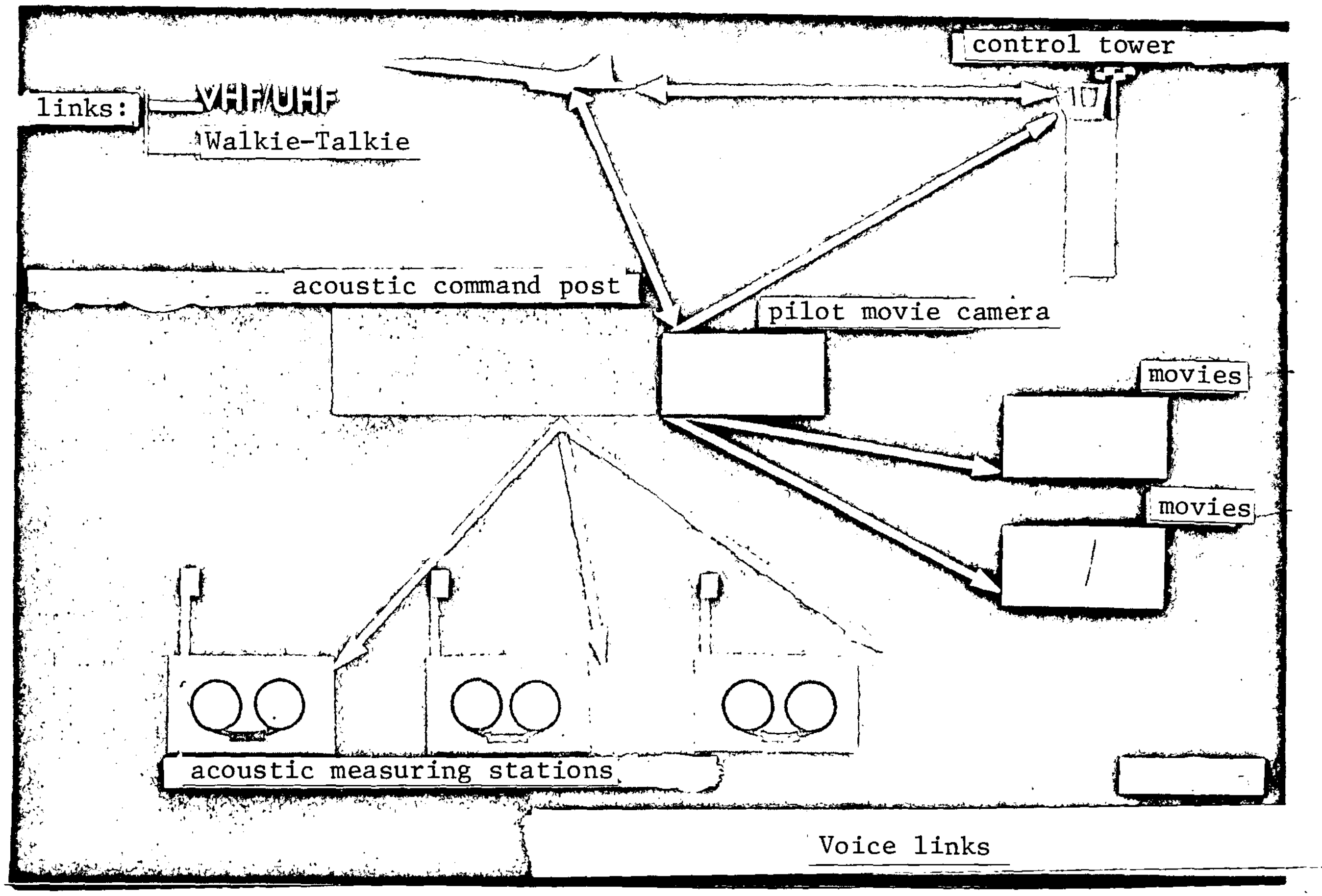
The pressure, temperature, humidity and wind are measured at three measuring stations which are far from each other. They are made at the cinetheodolite stations and at the control tower.

In addition, the balloon probes are launched and followed by a cinetheodolite before and after each flight series. This is done in order to determine abnormal wind gradients with altitude.

A static temperature probe with a small response time installed on the aircraft makes it possible to determine a temperature inversion during takeoff and landing maneuvers.

6.3.2. Ambient Noise

The ambient noise and the electrical background noise of the measurement chain are recorded for each pass of the aircraft with the sensitivity utilized during the measurement. This is carried out by operating



control tower
links:
VHF/UHF
Walkie-Talkie
acoustic command post
pilot movie camera
movies
movies
acoustic measuring stations
Voice links

Figure 16

the measurement stations approximately 15 seconds before the beginning of the pass of the aircraft.

6.3.3. Limiting Conditions

In order to obtain measurements which are correct and which can be transformed to standard conditions, it is necessary to observe the following very accurate test limits:

- wind less than 5 m/s

- humidity between 30 and 90%. Outside of these limits, the transformation to standard conditions is delicate. On the other hand, for increased humidity, there is a serious danger of short circuits in the microphones. This is because there is a possibility of water vapor condensation on the membrane.

- no mist or clouds at an altitude less than 3000 feet. If this is not the case, it is no longer possible for the cinetheodolites to track the aircraft.

6.4. Test Programs /12

The flight programs are determined in such a way that there will be a sufficient definition of the sonic field. Also, it must be possible to analyze the data in a simple way on the computer.

The flight programs consist of level segments, ascending or descending stable segments depending on the flight regimes indicated on the engines. The selection of the overflight altitude essentially depends on the definition of the required sonic field. In effect, the spectra are recorded every one half second. If the altitude of the pass is 200 meters, the angles corresponding to two consecutive spectra in the maximum noise zone will be separated by five degrees. For an altitude of 30 meters they will be separated by forty degrees. Even though the lowest possible altitude is desirable in order to minimize parasitic propagation effects as much as possible, a compromise must be reached at a minimum altitude of about 100 meters. The same type of problem arises when the aircraft passes take place at a high velocity. It is then necessary to raise the altitude.

7. EVALUATION

7.1. General Remarks

The evaluation program produced at the S.N.E.C.M.A. for a IBM 360-44 computer contains more than 1000 Fortran instructions and 20 sub-programs.

The data are supplied in various forms:

- a numerical magnetic tape containing acoustic analyses;
- a numerical magnetic tape containing the trajectory data;
- a series of punched cards.

The results of the calculation are given:

- in listed form;
- on punched cards (spectra of interest for later calculations)
- by plotted curves (sonic fields and spectra of the noise maximum).

The following can be done with a program: /13

a) two evaluation conditions:

  - for daytime atmospheric conditions
  - for standard atmospheric conditions

b) the overflight can be transposed by any arbitrary reference distance.

7.2. Calculations

All the calculations are applicable either for acoustic certification or for general studies.

7.2.1. Annoyance Calculations

For each spectrum, the program can calculate levels in PNdB and corrections to the discrete frequency according to the latest international recommendations.

For a complete overflight, the program gives the final value in EPNdB by performing a calculation by integration of the duration correction. Figure 17 shows an example of the results for the daytime conditions and a corresponding transposition for the same overflight.

7.2.2. Directivity Calculations

For each spectrum, the program calculates the angle between the axis of the engine and the line connecting the corresponding position of the aircraft and the microphone, at the instant the noise signal is received. This calculation involves the leveling angle of the engines on the aircraft, the incidence angle and the sideslip angle. In effect, the most important angle for prediction methods is the one corresponding to the instant at which the noise is emitted. The distance flown by the aircraft during the propagation time must be found in order to calculate it. The results have shown that, for the maximum noise, the deviation between the two angles is about 15°. This is very important, and shows that for directivity studies it is absolutely necessary to utilize angles at the instant the noise is emitted.

Example of Evaluation of an Acoustic Test of an Aircraft Flight

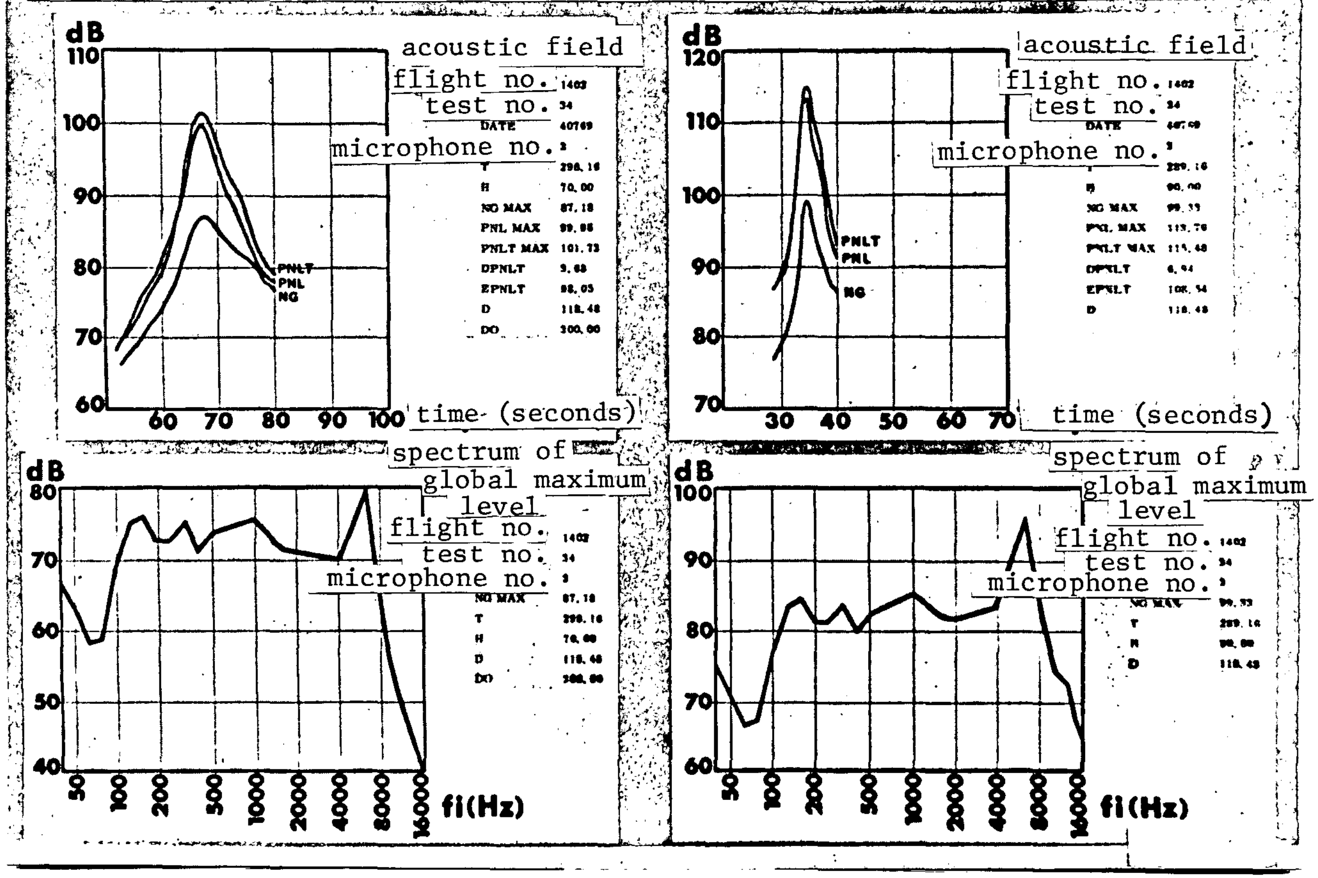


Figure 17

7.3. Remarks on the Evaluations

7.3.1. Statistical Study

During a particular flight, a large number of consecutive overflights were recorded using several microphones. Theoretically, the overflights were identical. The statistical evaluation of these tests (using the Student-Fisher law) made it possible to calculate the confidence interval associated with different values of interest of the maximum noise: total level, level by 1/3 octave, PNdB, EPNdB, and directivity.

Figure 18 shows an example of results for one microphone and nine consecutive overflights. For these conditions, the calculation, which is also carried out for other measurement chains, shows that the 90% confidence interval on the value of EPNdB is 0.4 and is 4° for the angle. The confidence interval is improved only very slightly by transforming the overflights to the reference conditions.

The confidence intervals lie between 1 and 1.5 EPNdB for seven other measurement chains and for only three overflights.

In practice, for general study tests, it is therefore necessary to make at least three overflights in order to obtain significant results.

The same type of statistics was determined considering the same overflight recorded by several microphones. For three overflights with ten microphones, the confidence intervals are 0.4 EPNdB and 4°, which is equivalent to the preceding result.

For five overflights with three microphones, the confidence interval is 1 EPNdB, which is a result which is slightly better than before. This is due to the fact that this type of statistic only involves the dispersion of the motor parameters, the trajectory parameters and the atmospheric conditions.

Example of the Results of a Statistical study

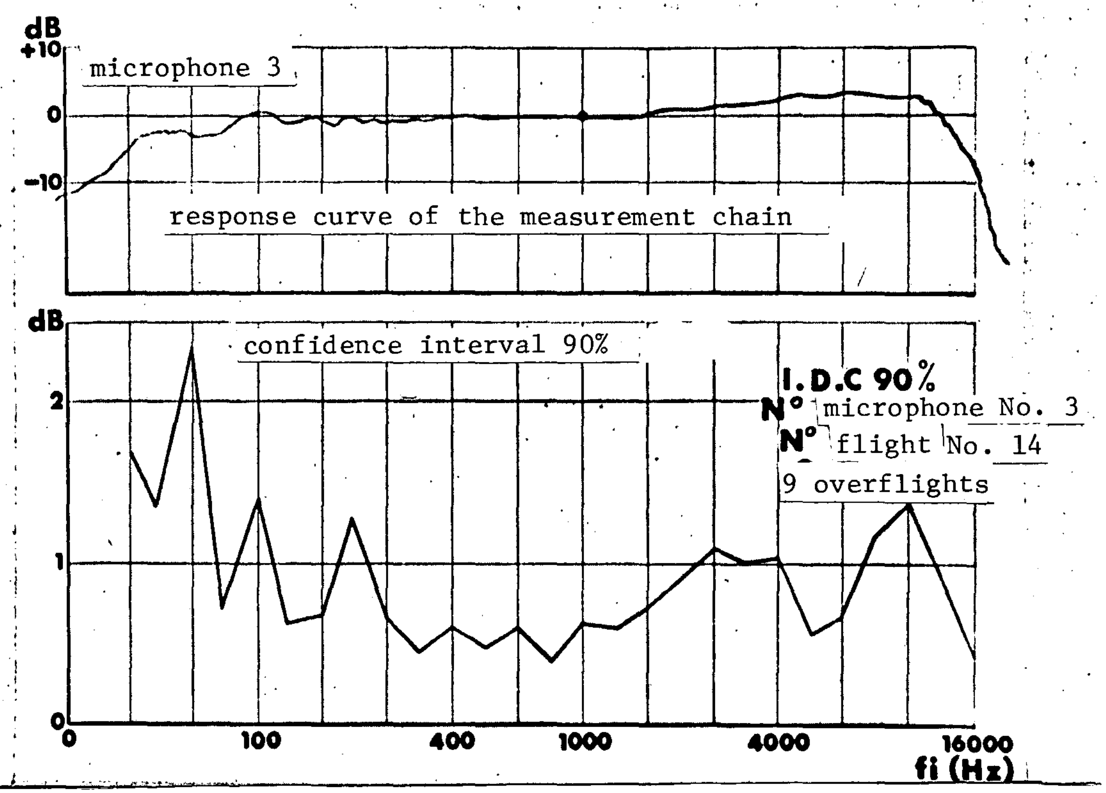


Figure 18

The calculation was also carried out using 54 recordings. The confidence interval then becomes 0.2 EPNdB and 1.5° for the angle of maximum noise.

7.3.2. Phenomena which Increased the Dispersion of the Measurements /15

This statistical study showed the importance of using measurement chains which are in perfect order and are set very accurately.

Figure 19 shows the results obtained with a measurement chain where the tape recorder is seriously defective. It can be seen that the confidence interval of the spectral components is very bad, especially in the frequency region where the tape recorder has a defective response curve.

This Figure also shows another type of dispersion which occurs at low frequencies. This time it is a phenomenon introduced by the reflections of the noise on the ground, which is therefore completely independent of the measurement chain. For the geometry of this overflight, the theoretical interference extremes are located in the 1/3 octaves 63 - 160 - 200 - 315 and 400 Hz. Examination of these recordings shows displacements of 1/3 octaves of these extremes in accordance with these overflights. This explains the large corresponding dispersion. However, it should be noted that this phenomenon has practically no effect on the total level (dB - PNdB or EPNdB).

8. CONCLUSIONS

Using this equipment, two complete test programs were carried out with the aircraft MYSTERE 20 and CANBERRA, as well as tests on the CONCORDE 001 in conjunction with the Société Nationale des Industries Aérospatiales (National Society of Aerospace Industries) and the British Aircraft Corporation.

During the programs, 2500 recordings of aircraft overflights were recorded. Of this total, approximately 14% could not be evaluated, either because of a failure in a measurement station, because the recording tape was not exactly

Influence of Control of Measurement Chains

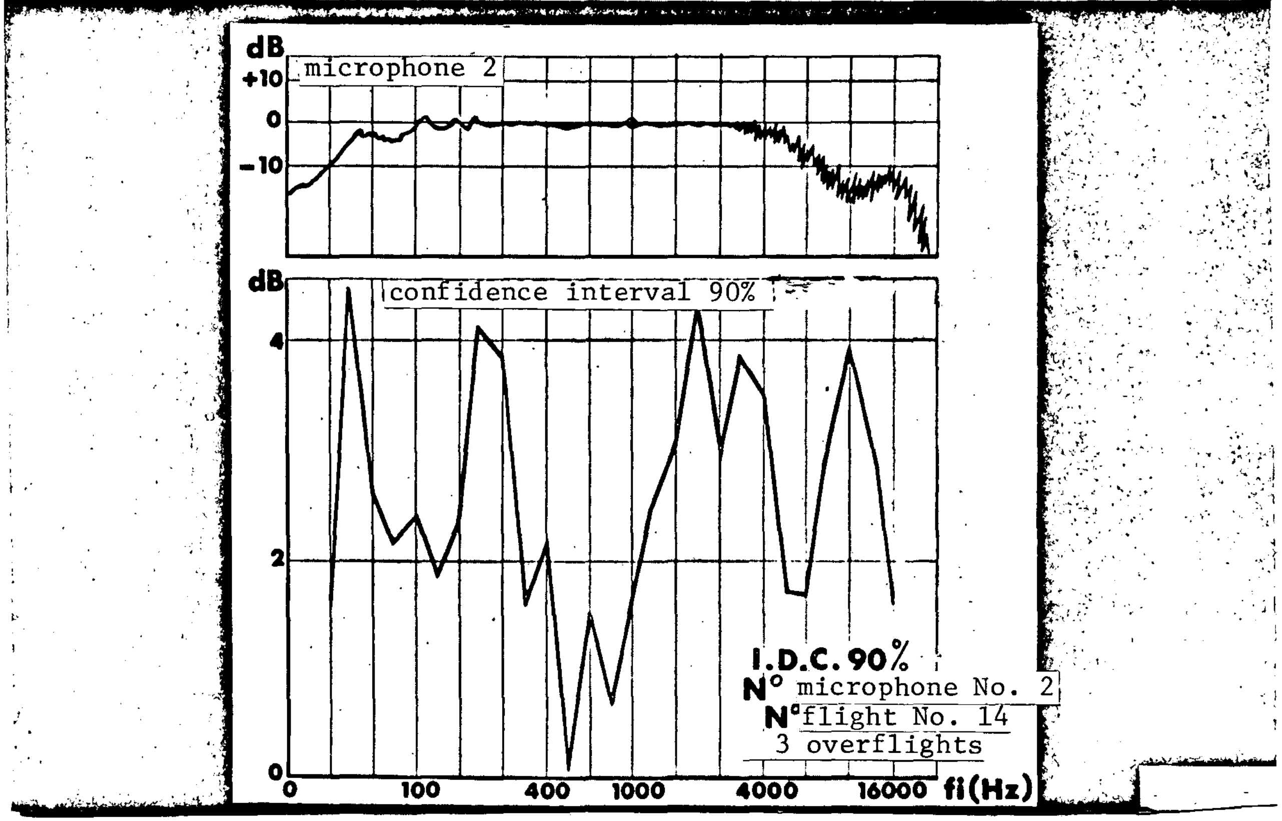


Figure 19

up to the required standard or because the aircraft noise was too weak and did not exceed the ambient noise by a sufficient amount. The tests were carried out using 15 measurement chains. On the average, two stations failed completely, which did not disturb the evaluation because of the redundancy of the results.

Several improvements of the system are presently in progress. On the equipment level, the reliability of the components in each chain has been improved as well as the range of the remote control. Studies are now in progress for the perfection of a trajectory analysis system which will operate in real time. As far as the analysis is concerned, the O.N.E.R.A. /16
chain is complete in that it operates completely automatically. A computer CII 10020 to be integrated into this system will be operational in 1971. At the evaluation level, the programs are being modified so that a better interpolation of the trajectory can be obtained and so that the overflights can be transformed to zero incidence. In addition, the magnetic tape outputs by the analysis are transferred to IBM 2315 discs and utilized in a direct access mode. This makes it possible to considerably reduce the access time for an arbitrary overflight during the calculation.

We would like to emphasize the contributions of Mr. Avelard and Mr. Gobin of the O.N.E.R.A. and their collaborators in the development of this material.

Translated for National Aeronautics and Space Administration under contract No. NASw 2035, by SCITRAN, P. O. Box 5456, Santa Barbara, California 93108.